AD-A068 110 ITT ELECTRON TUBE DIV EASTON PA F/G 9/1

LONG LIFE X-RAY TUBES FOR AN/TAQ-2 SYSTEM.(U)

APR 79 C L SHACKELFORD DAAB07-77-C-2657

UNCLASSIFIED DELET-77-2657-F NL

1 OF 1

ADA

068110

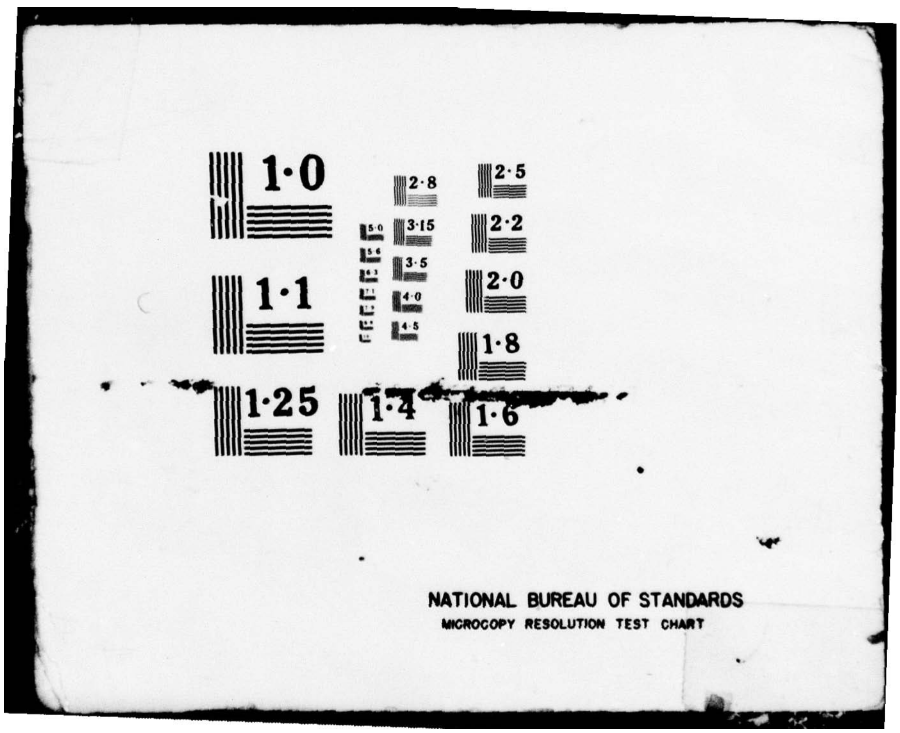
END

DATE

FILMED

6-79

DDC


1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
1·1
4·5
1·8
1·25
1·4
1·6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Research and Development Technical Report
DELET—TR—77-2657-F

LONG LIFE X-RAY TUBE FOR AN/TAQ-2 SYSTEM

Charles L. Shackelford
ITT Electron Tube Division
3100 Charlotte Avenue
Easton, Pennsylvania 18042

April, 1979

Final Report for the Period 15 April 1977 to 28 February 1979

DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited

ERADCOM
US ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY 07703

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(19) REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (18) DELET-77-2657-F	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) LONG LIFE X-RAY TUBES FOR AN/TAQ-2 SYSTEM.		5. TYPE OF REPORT & PERIOD COVERED (9) Final rept. 15 Apr 77 ~~to~~ 28 Apr 79
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Charles L. Shackelford		8. CONTRACT OR GRANT NUMBER(s) (15) DAAB07-77-C-2657
9. PERFORMING ORGANIZATION NAME AND ADDRESS ITT Electron Tube Division 3100 Charlotte Avenue Easton, PA 18042		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62705 (17) 1L62705AH94 E1.10
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Electronics Technology & Devices Laboratory ATTN: DELET-BG Fort Monmouth, NJ 07703		12. REPORT DATE (11) April 1979
		13. NUMBER OF PAGES 16
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (16) 1L762705AH94		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited. (12) 25p.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

X-ray
Field Emission
Electron Tube
Single Crystal

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A series of modifications has produced an x-ray tube for the AN/TAQ-2 system having at least six times the life of the tube in present use. This was achieved principally by modifying metallurgical properties of the tube anode.

A tube using a single crystal tungsten anode was demonstrated to have more than ten times the life of the present tube.

A proposed MIL specification was written for the long life tube.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

189720

79 04 30 042

TABLE OF CONTENTS

		Page
Report Documentation		i
List of Figures		iii
1.0	Foreward	1
2.0	Object	1
3.0	Background	1
4.0	Single Crystal Tungsten Anodes	2
5.0	Ceramic Envelope Tubes	6
6.0	Final Tube Design	7
7.0	Equipment Considerations	10
8.0	Conclusions	11
	Appendix - Proposed Military Spec Sheet Electron Tube, X-Ray Type	

List of Figures

Number	Title	Page
1	Life Test Results for .150 Single Crystal Anode	3
2	Life Test Results for .250 Single Crystal Anode	5
3	Cross Section of Long Life Tube	8
4	Life Test Results for Proposed Long Life Tube	9

1.0 FOREWARD

This report covers work done during the period 15 April 1977 to 28 February 1979 on Contract DAAB07-77-C-2657 to develop a long-life x-ray tube for the AN/TAQ-2 x-ray system. The work was performed by the ITT Electron Tube Division in Easton, Pennsylvania for the U. S. Army Electronics Research & Development Command, Ft. Monmouth, New Jersey.

2.0 OBJECT

The object of the work was to improve the x-ray tube used in the AN/TAQ-2 Portable X-Ray Generator System according to the requirements of Beam, Plasma Display Technical Area Guidelines entitled: "Long-Life X-Ray Tube for AN/TAQ-2 System," dated 1 June 1976.

3.0 BACKGROUND

In work performed 1 June 1975 to 31 May 1976 under Contract DAAB07-75-C-1334, the ITT Electron Tube Division was able to improve the tube life for the then existing x-ray tube for the AN/TAQ-2 system by a factor of three at 100KV operation and approaching a factor of two at 150 KV operation. An Alternate approach which accepted a slightly lower x-ray output extended the life five to six times that of the previous standard tube.

The principal change which affected life was the reduction in the number of crystal boundaries on the anode surface which could be eroded by the bombarding electrons necessary to x-ray generation. The work herein reported continued the study of changed metallurgical properties of the anode and of other modifications to the existing commercial tube design to adapt it for long life service in the AN/TAQ-2 system.

4.0 SINGLE CRYSTAL TUNGSTEN ANODES

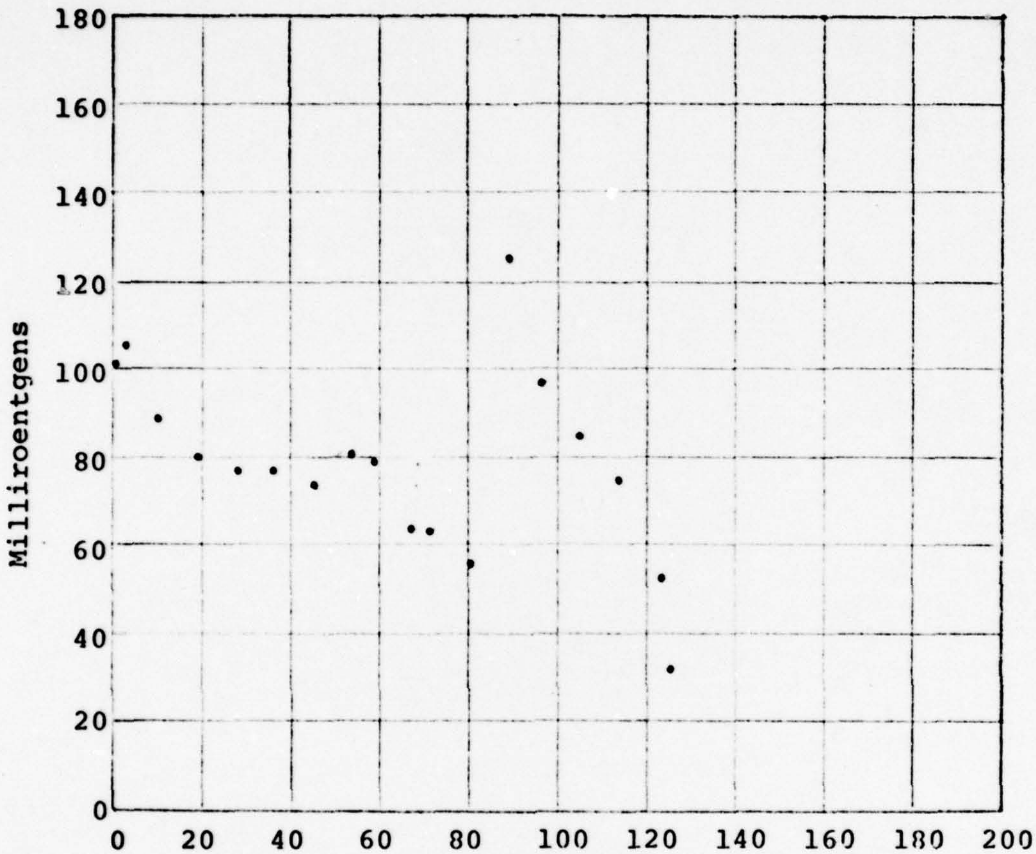
Previous investigation indicated that the rate of anode erosion was a function of the amount of exposed crystal boundaries on the anode surface. A significant increase in the tube life was obtained with anodes that were heat treated to reduce the length of exposed boundaries.

To start the present study, single crystal tungsten anodes were obtained in two sizes and in both axially oriented and random oriented grain direction. It was reasoned that the ultimate in boundary reduction would be achieved with this material.

The first life tested tube using this material contained an anode of the same size and shape as that used in the present commercial tube. This tube, #5440, also had a baffle added to its cathode structure to trap sputtered anode material before it could be deposited on the glass envelope. The life performance of this tube is shown in Figure 1.

The best previous performance of heat treated anodes obtained from this size anode was 96,000 pulses with the normal life being 60,000 to 80,000 pulses for the same x-ray output end point. The standard commercial tube produces a life in the 20,000 to 40,000 pulse region.

The sudden increase in x-ray output at about 90,000 pulses has no completely satisfactory explanation. It is normal for these tubes to show a form of periodic deviation in output during life but not to the noted extent. The tube impedance and hold-off voltage did not change. The most likely explanation is that the actual x-ray



Life - Thousands of Pulses

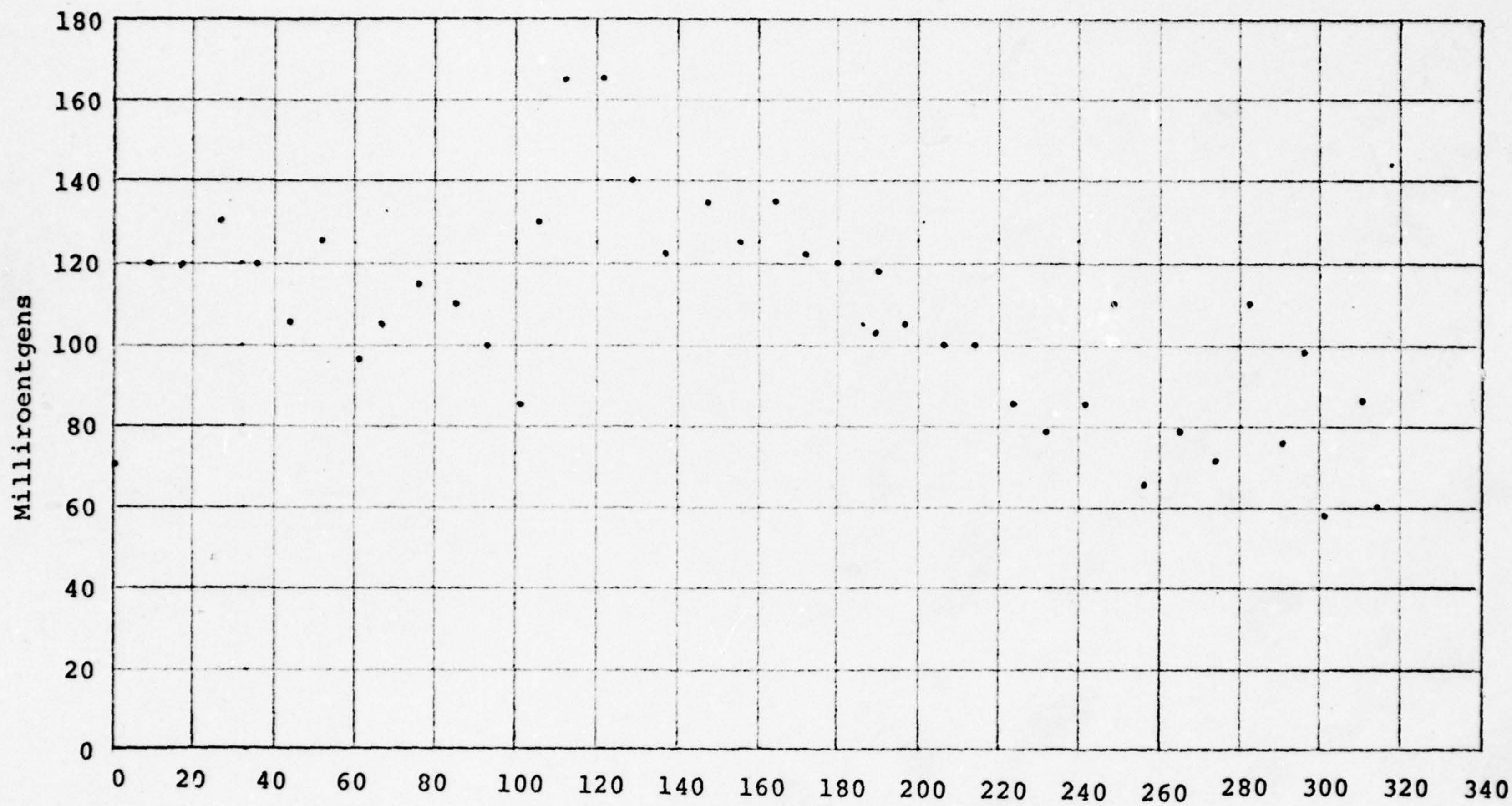
Tube #5440 .150 X 14° Single Crystal Tungsten Anode
25 Pulse Groups
100 kv at 12" in AN/TAQ-2 System

Figure 1

pulse width as compared to the applied voltage pulse width increased for a period of several thousand pulses for some internal geometric reason having to do with anode erosion. The anode in this tube was almost completely consumed. The increase in life, while substantial, was not as much as was desired.

The anode of #5440 was shaped as a cone of 0.150 inches base diameter with an included angle of 14°. During the previous study, some life data were obtained from tubes having anodes with a base diameter of .250 inch and an included angle of 28°. These data indicated that a life in the 150,000 to 175,000 pulse region might be expected if proper metallurgical control could be exercised over the anode. A tube having a single crystal anode in this larger size was life tested. Figure 2 shows the life of this tube, #5444, for the same operating conditions as for the test shown in Figure 1. This test was arbitrarily stopped. The anode erosion was uniform and the tube would likely have lasted for thousands more pulses.

The test was stopped to save wear on the test gear and because it had become apparent during the construction of the single crystal anode tubes that considerations other than the life to be obtained were more important from a practical standpoint. The tungsten crystals were machined to shape by the spark machining process. Conventional machining operations would set up surface stress that would result in the crystal cracking and effectively result in the creation of boundaries between grains, thus negating a desired property of the material. The state-of-the-art for such machining of this material has apparently not progressed to the point



Life - Thousands of Pulses

Tube # 5444 .250 X 28° Single Crystal Anode 25 Pulse Groups
100 kv at 12" in AN/TAQ-2 System

Figure 2

where satisfactory control of surfaces, tolerances, and general quality will permit the parts to be assembled using normal tube making techniques. Each attempt to construct a single crystal anode tube required changed tooling and individual adjustment of the components to give the desired geometry. An attempt was made to use electrolytic milling to correct some of the existing variations but the relative activities of the different crystal faces resulted in anodes more pyramidal than conical. It was apparent that the heat treated tungsten anodes previously studied were a more cost effective solution to the long life problem.

5.0 CERAMIC ENVELOPE TUBES

An attempt was made to build a ceramic envelope x-ray tube to fit the AN/TAQ-2 system. A test of this tube would show whether or not a life gain could be realized from the higher processing temperatures that may be employed with a ceramic envelope tube. The construction used was illustrated in the first report of this present series.

No successful tube was made. When the tube was operated in the remote head of the AN/TAQ-2, the joint between the ceramic portion of the tube and the plastic insulating extension would not hold voltage. Several different high voltage elastomer adhesives were tried. None would last more than a few hours of operation.

The life obtained from concurrent glass tube tests indicated that as in the case of the single crystal tungsten, the ceramic envelope would not be a practical solution for this application and work to find an improved elastomer and high voltage resistant joint was dropped.

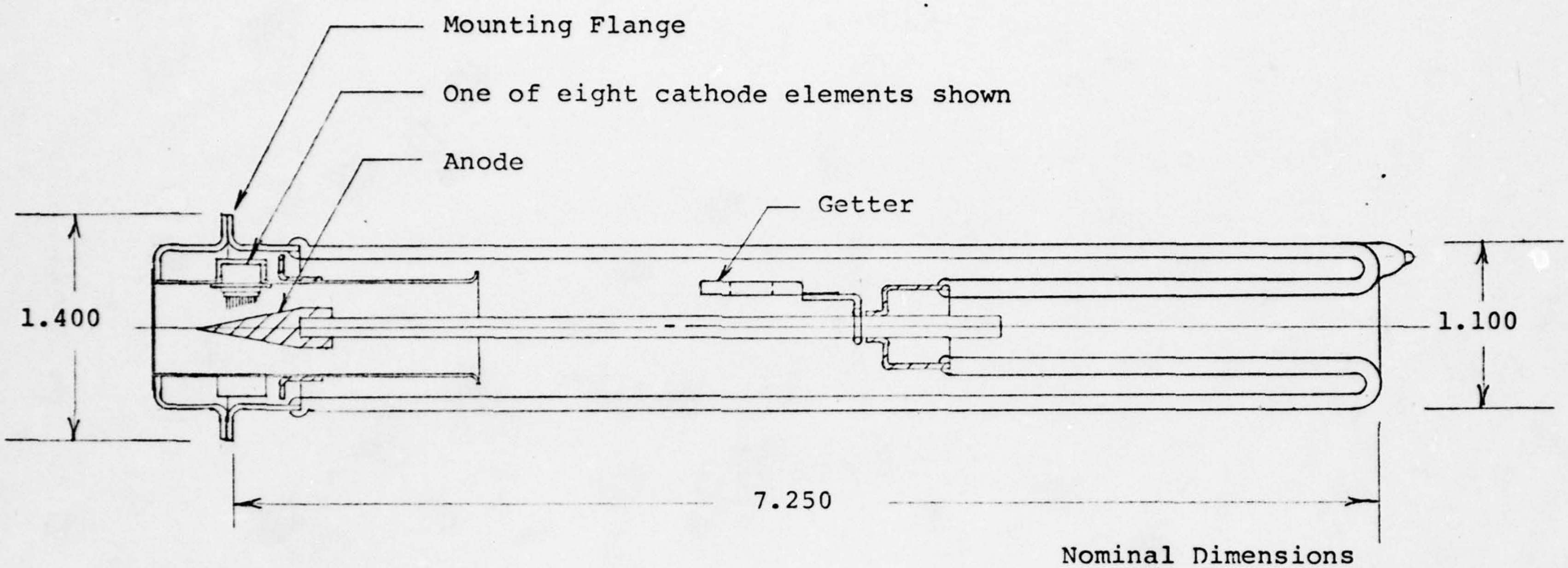
6.0 FINAL TUBE DESIGN

Figure 3 is a cross section of the tube resulting from this series of tests. The anode tip is ground from polycrystalline tungsten and then heated to promote grain growth. The cathode structure holds the field emission cathode elements at the proper location and shields the glass envelope from sputtered anode material. A getter is fixed to the anode shank.

Two methods of anode heat treatment have been used: 1) electron beam heating, which is the easiest to control and 2) argon arc heating, which was used for the anode of tube #5450 whose life results are shown in Figure 4. A temperature of over 2500°C for 15 to 20 seconds is necessary for the degree of grain growth needed.

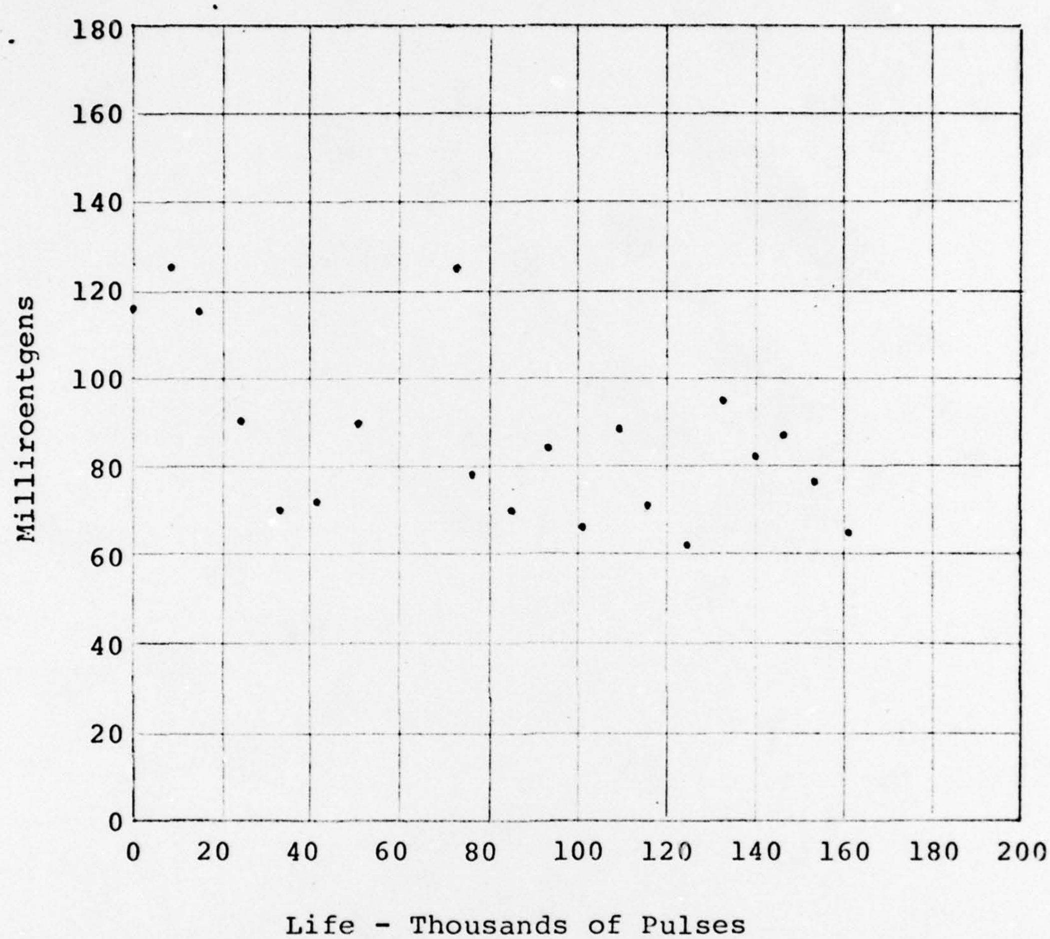
The anode is larger than that of the commercial tube and this contributes to the increased life. The principal objection to an increased anode diameter is discussed in the final report on Contract DAAB07-75-C-1334. There is a theoretical reduction in forward x-ray intensity for the larger anode for equal excitation. There is a possibility of a larger focal spot. Both of these objections are more theoretical than real. The random nature of the emission from the cathode points seems likely to introduce more variation than the amount of forward intensity reduction. In any event, the x-ray output is adequate for the purpose.

The possibility of a larger focal spot occurring on the larger anode seems valid; however, tests show that it is essentially the same size as that of the smaller anode. Experiments conducted by the Beam, Plasma, and Display Technical Area, Ft. Monmouth, NJ have



Cross Section of Long Life Tube

Figure 3



Tube #5450 .250 X 28° Heat Treated Anode
25 Pulse Groups
100 kv at 12" in AN/TAQ-2 System

Figure 4

shown no essential difference in picture definition between the two anode sizes. The possibility still exists that a tube approaching its end-of-life might produce a larger focal spot.

- The larger cone angle of the larger anode promotes beam uniformity and tests on present tubes show a response better than that required by the previously referenced Guidelines.

Tube #5450 failed because of an incidence of equipment failure. The data indicate that the life would likely have been several thousand pulses longer. The type of failure was one to which the tube might have contributed because of a deteriorating anode contact area. Future tubes will be so constructed that this possibility will not exist.

A flashless getter is used in the tube. This getter is most effective at room temperature and is an excellent getter for hydrogen which is the principal gas released from the electrodes during operation.

7.0 EQUIPMENT CONSIDERATIONS

The life tests for this and the previous study were run in AN/TAQ-2 systems and their commercial equivalent. This series of tests were the equivalent of many normal lifetimes for the equipment. Because of continuing wear-out problems with the equipment and consequent time loss in obtaining repairs, the proposed 150 KV life tests were not performed. Data obtained during the previous study indicated a life at 150 KV of approximately one-half that obtained at 100 KV.

The tubes resulting from this study appear to be of such durability that relatively few would be used during the lifetime of the remainder of the system.

8.0 CONCLUSIONS

The goal of improving upon an existing commercial design to produce a long life tube for the AN/TAQ-2 system has been met. The tube life for equivalent performance has been extended by at least a factor of six. Information has been obtained which will allow further extension of life upon an advance in the state-of-the-art of single crystal tungsten machining.

It was determined that a ceramic envelope tube would not be cost effective compared with the glass envelope tube even if a suitable high voltage elastomer is found. The present glass envelope tube appears sufficiently rugged in a mechanical sense and a ceramic envelope does not appear necessary from this standpoint.

A proposed MIL specification for the tube is an appendix to this report. To a large extent, the tests and ratings follow the Beam, Plasma and Display Technical Area Guidelines dated 1 June 1976. The various tests peculiar to this class of tube are detailed in the specification because they are not presently included in MIL-STD-1311.

APPENDIX

Proposed
Military Specification Sheet
Electron Tube, X-Ray
Type

Proposed

Military Specification Sheet

Electron Tube, X-Ray

Type

The complete requirements for procuring the electron tube described herein shall consist of this document and the latest issues of specification MIL-E-1 and Federal Standard No. 83.

Description: Cold Cathode Pulse X-Ray Tube with .003 inch nickel filter

Mounting Position: Any

Weight: 3.5 ounces (99 grams) Nominal

Figure 1

Absolute Ratings:

Parameter:	epy	prr	Dose	Source	Beam Angle	Impedance	TA
Unit:	kv		mr	mm	Degree	ohm	°C
Maximum:	150			4.0			+75
Minimum:			Note 1,2,3	Note 2	35	90	-55
Test Condition:	100	20				Nominal	

General:

Qualification - Required

Method	Requirement or Test	Notes	Conditions	Symbol	Limits Minimum	Limits Maximum	Unit
	Quality Conformance Inspection, Part 1						
	Output (1)	2,3	100 kv, 12 inches 25 pulses	-	65		mr
	Pulse to Pulse Uniformity	2,3,4	100 kv, 12 inches	-	-	-	-
	Quality Conformance Inspection, Part 2						
	Output (2)	2,3	150 kv, 24 inches 25 pulses	-	55		mr
	Beam Uniformity	2,3,5	100 kv, 12 inches	-	-	-	
	Quality Conformance Inspection, Part 3						
	Focal Spot Size	2,3,6	100 kv	-	-	4.5	mm
1031	High Frequency Vibration	7,8	No voltage applied	-	-	-	-
	Vibration End Paint		Output (1)		65		mr
	Life	8	100 kv, Group c		150,000		pulse
	Life End Paint		Output (1)		50		mr

Note 1 - The rated minumum dose from the tube in an AN/TAQ-2 or equivalent x-ray system is 65 mr at 12 inches for 100 kv operation or 55 mr at 24 inches for 150 kv operation integrated over 25 pulses.

Note 2 - The tube output is measured during operation in an AN/TAQ-2 x-ray system or equivalent circuit. The applied voltage is a square pulse of the specified peak value and of (60 ±5) 10^{-9} seconds duration. The sum of the rise and fall portions of the pulse is not greater than 20 X 10^{-9} seconds. The voltage source has a characteristic impedance of 90 ohms. The repetition rate for 100 kv operation is 20 pps; for 150 kv, 14 pps. The duty cycle is 2.5 X 10^{-8}, maximum.

Note 3 - Output measurements are made with a Victoreen 544, or equivalent ion chamber integrating meter located with the chamber centered on the beam and at the specified distance from the x-ray tube window.

Note 4 - Pulse to pulse uniformity is measured by recording 10 groups of 10 pulses each. Five consecutive groups shall not vary from the 10 group average by more than ±15 percent.

Note 5 - Predetermine the member of 100 kv pulses necessary to produce approximately 100 mr at 12 inches. Expose any non-screen industrial x-ray film in a cardboard holder at 12 inches with the film centered on the beam using the determined number of pulses but not less than 20. Develop the film to completion. Using a Macbeth TD-102 or equivalent transmission densitometer, measure the density on the beam axis. Make sets of four orthogonal measurements on each of six inch and four inch diameter circles centered on the beam. The six inch circle measurements shall be not less than 70 percent of the center density. The four inch circle measurements shall differ not more than 10 percent from each other.

Note 6 - The focal spot size is measured by the method of Federal Standard No. 83 with the following exceptions:

1. Thirty pulses are used with the distance from the focal spot to the lens at 12 inches.

2. Polariod film with a fluorescent screen may be substituted for the specified dental film. An optical micrometer may be used to measure the image dimensions.

3. The method of image size calculation is modified to consider a circular or oval image instead of a rectangular one. If A and B are the major and minor axes of the image, the image size is

$$C = \frac{\sqrt{AB}+B}{3}$$

The focal spot size is

$$f = C - 2d \text{ for } f \geq 2.5 \text{ mm}$$

$$f = \frac{C - 3d}{2} \text{ for } f < 2.5 \text{ mm}$$

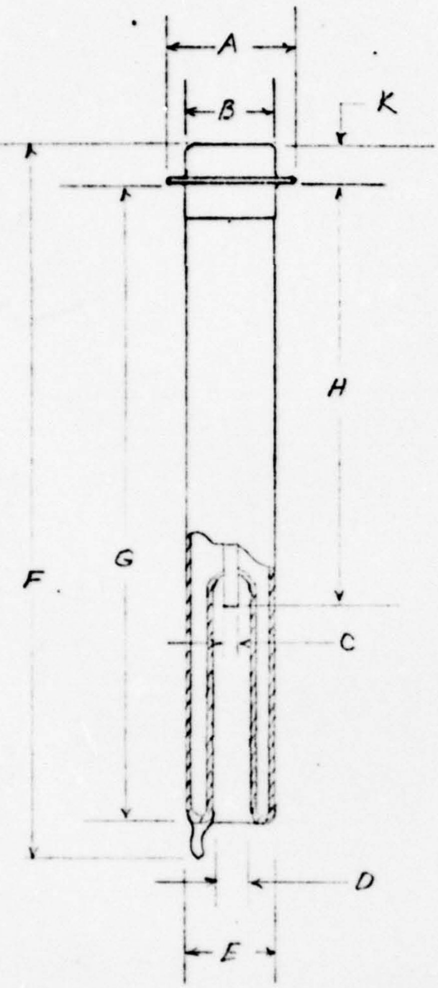
d is the diameter of the pin hole lens.

An image that is distorted into a distinct lunar shape is cause for rejection.

Note 7 - The tube shall be supported solely by its mounting flange.

Note 8 - This test shall be performed during the initial production and once each succeeding 12-calendar months in which there is production. A regular double sampling plan shall be used, with the first sample of three tubes with an acceptance number of zero, and a second sample of three tubes with a combined acceptance number of two. In the event of failure, the test will be made as part of quality conformance inspection, part 2, code level D, with an AQL of 6.5. The regular "12-calendar month" double sampling plan shall be reinstated after three consecutive samples have been accepted.

Note 9 - End point readings will be taken at intervals of not more than 10,000 pulses. These readings also constitute part of the accumulated life.



Ltr	Dimensions in inches with metric equivalents (mm) in parenthesis	
	Minimum	Maximum
Quality conformance inspection, part 2		
A	1.380 (35.1)	1.515 (38.5)
D	.450 (11.4)	—
E	—	1.093 (27.8)
G	7.125 (181.0)	7.325 (186.1)
Quality conformance inspection, part 3		
B	—	1.032 (26.2)
C	.125 (3.2)	—
F	—	8.187 (208.0)
H	4.700 (119.4)	4.800 (122.0)
K	—	.531 (13.5)

Figure 1

Outline Drawing of Electron Tube Type

DISTRIBUTION LIST

12 Defense Documentation Center
ATTN.: DDC-TCA
Cameron Station (Bldg. 5)
Alexandria, VA 22314

1 Code R123, Tech. Library
DCA Defense Comm. Engineering Center
Reston, Va 22090

1 Defense Communications Agency
Technical Library Center
Code 205 (P.A. TOLOVI)
Washington, DC 20305

1 Office of Naval Research
Code 427
Arlington, VA 22217

1 Director
Naval Research Laboratory
ATTN: Code 2627
Washington, DC 20375

1 Commander
Naval Electronics Laboratory Center
ATTN: Library
San Diego, CA 92152

1 CDR, Naval Surface Weapons Center
White Oak Laboratory
ATTN: Library, Code WX-21
Silver Spring, MD 20910

1 Rome Air Development Center
ATTN: Documents Library (TILD)
Griffiss AFB, NY 13441

1 Hq., Air Force Systems Command
ATTN: DLCA
Andrews AFB
Washington, DC 20331

2 CDR., MIRCOM
Redstone Scientific Info Center
ATTN: Chief, Document Section
Redstone Arsenal, AL 35809

1 Commander, MIRCOM
ATTN: DRSMI-RE (Mr. Pittman)
Redstone Arsenal, AL 35809

3 Commandant
U. S. Army Aviation Center
ATTN: ATZQ-D-MA
Fort Rucker, AL 36362

1 Director, Ballistic Missile Defense
Advanced Technology Center
ATTN: ATC-R, P.O. Box 1500
Huntsville, AL 35807

1 Commander
HQ Fort Huachuca
ATTN: Technical Reference Div.
Fort Huachuca, AZ 85613

2 Commander
U.S. Army Electronic Proving Ground
ATTN: STEEP-MT
Fort Huachuca, AZ 85613

1 Commander
USASA Test & Evaluation Center
ATTN: IOA-CDR-T
Fort Huachuca, AZ 85613

1 Deputy for Science & Technology
Office, Asst. Sec. Army (R&D)
Washington, DC 20310

1 CDR., Harry Diamond Laboratories
ATTN: Library
2800 Powder Hill Road
Adelphi, MD 20783

1 Director
U.S. Army Ballistic Research Labs
ATTN: DRXBR-LB
Aberdeen Proving Ground, MD 21005

1 Harry Diamond Laboriatories, Dept. of Army
ATTN: DRXDO-RCB (Dr. J. Nemarich)
2800 Powder Hill Road
Adelphi, MD 20783

1 Commander, TARCOM
ATTN: DRDTA-RH
Warren, MI 48090

1 CDR., U.S. Army Aviation Systems Command
ATTN: DRSAV-E
P. O. Box 209
St. Louis, MO 63166

1 TRI-TAC Office
ATTN: TT-SE (Dr. Pritchard)
Fort Monmouth, NJ 07703

1 CDR., U.S. Army Research Office
ATTN: DRXRO-IP
P. O. Box 12211
Research Triangle Park, NC 07709

1 CDR., U.S. Army Research Office
ATTN: DRXRO-PH (Dr. R. J. Lontz)
P. O. Box 12211
Research Triangle Park, NC 27709

1 Commandant
U.S. Army Air Defense School
ATTN: ATSA-CD-MC
Fort Bliss, TX 79916

1 Commander, DARCOM
ATTN: DRCDE
5001 Eisenhower Ave.
Alexandria, VA 22333

1 Chief
Office of Missile Electronic Warfare
Electronic Warfare Lab, ECOM
White Sands Missile Range, NM 88002

Commander
U. S. Army Electronics Command
Fort Monmouth, NJ 07703

1 DRSEL-WL-D
3 DRSEL-CT-D
1 DRSEL-TL-DT
3 DRSEL-TL-BG
1 DRSEL-TL-BG (Ofc. of Record)
2 DRSEL-MS-TI
1 DRSEL-TL-D
10 Originating Office

2 MIT - Lincoln Laboratory
ATTN: Library (RM A-082)
P. O. Box 73
Lexington, MA 02173

1 NASA Scientific & Tech. Info. Facility
Baltimore/Washington Intl. Airport
P. O. Box 8757, MD 21240

2 Advisory Group on Electron Devices
201 Varick Street, 9th Floor
New York, NY 10014